



CUTTING FLUID OILY WASTEWATER: BREAKDOWN AND REUSE OF THE RECOVERED OIL PHASE

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ABSTRACT

The aim of this work is to evaluate the use of electrolytes in the breakdown of waste by cutting fluid emulsions, reusing the recovered oil phase to develop new cutting fluids. Four cutting fluids were used to obtain oily emulsions: two commercial, OP38 (Lubrax) and Dromus (Shell), and two developed formulations, CF1 and CF2. The emulsions were prepared by using 5 to 30 wt.% cutting fluid in water. NaCl and CaCl₂ solutions were used to promote the destabilization of emulsions, taking into account the percentage of oil recovered as a function of time, observing the influence of type and concentration of electrolyte, temperature, and emulsion droplet size. The aqueous effluent obtained after oil phase removal was characterized by turbidity, oil and grease content, pH, and presence of anions and cations. The use of CaCl₂ (2 wt.%), at 25°C, provided the best results in emulsion breakdown and the best quality of the water phase. All the parameters evaluated in these water phases were in accordance with the specifications established by Brazilian legislation that regulates the disposal of wastewater in surface waters. The physicochemical properties of the recovered oil phases were compared with the ones of the mineral oil NH-20 used to obtain CF1 and CF2. It was verified an increase in total acid number, viscosity and corrosiveness to copper. Additives were added to the recovered oil phases to obtain new cutting fluids. The physicochemical properties of these new cutting fluids were close to the ones of the initial ones, except for the viscosity values which increased.

KEYWORDS

cutting fluid; oily wastewater; electrolyte; emulsion breakdown; oil reuse

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1. INTRODUCTION

Cutting fluids are usually composed by a mineral oil (40-80 wt.%), a surfactant, and additives. The surfactant can be used alone or as a blend of surfactants, depending on the formula's provision. The additives are included to the mixture to meet the specifications for commercial concentrates, such as resistance to bacterial growth and low corrosion capacity. Additionally, some cutting fluids may contain water in its composition (Bensadok et al., 2007; Bataller et al., 2004; Ríos et al., 1998).

Emulsions of cutting fluids are used in metal-mechanical industries to aid cutting processes, to prevent corrosion, and to improve lubrication, cooling, surface cleaning, and tool life. When used in machining processes, these emulsions lose its properties and effectiveness due to the thermal degradation and contamination. The replacement of these emulsions is responsible for the production of oily wastewaters (Bensadok et al., 2007; Canizares et al., 2008; Chang et al., 2001; Cheng et al., 2005; Kobya et al., 2008; Ríos et al., 1998; Sandin et al., 1991; Talbi et al., 2009).

Residual cutting fluids have a high carcinogenic potential due to the presence of products derived from the degradation of additives, polycyclic aromatic hydrocarbon (PAH), nitrosamines, among others. According to Soković and Mijanović (2001), secondary substances that are formed by the use of cutting fluids include reaction products, foreign bodies, and microorganisms. It is essential to treat the cutting fluid wastewaters before its disposal in the environment considering the risks presented and the presence of strict environmental regulations (Bartz 1998; Cheng et al., 2005; Feldman and Kessler, 2002; Srinivasan and Viraraghavan, 2010; Wright et al., 1993).

The mineral oil base of the cutting fluid is not modified with its use, making possible to recycle it several times by replacing the missing additives. Considering the poor biodegradability of the recovered oil phase, recycling is the best alternative to address these threatening residues. The reuse of the recovered oil phase in new cutting fluids prevents its disposal or burning and reduces the extraction of nonrenewable resources for the production of new ones.

The aim of this research is to study the use of electrolytes in the breakdown of cutting fluid

aqueous emulsions. It also seeks to develop novel ways to reuse the recovered oil phase in the production of new cutting fluids.

2. MATERIALS AND METHODS

2.1 Commercial cutting fluids

Two commercial cutting fluids were used to obtain the oil-in-water (o/w) emulsions: OP 38 (Lubrax), a miscible cutting fluid formulated with refined naphthenic base oil, emulsifier, corrosion inhibitors and biocides; and Dromus (Shell), a general purpose soluble oil containing a high level of emulsifiers for superior performance.

2.2 CF1 and CF2 cutting fluids

To prepare the developed cutting fluids, CF1 and CF2, it was used a hydrogenated naphthenic mineral oil as oil phase (NH-20, Petrobras); a medium molecular weight sodium sulfonate as emulsifier (Miracema Corporation); a trihydroxyethylamine oleate as corrosion inhibitor (Miracema Corporation); a triazine derivative as biocide agent (Miracema Corporation); and an organic polydimethylsiloxane-based antifoaming agent (Lubrizol Corporation), according Muniz et al. (2008). To obtain CF1 and CF2 the same amount of oil phase was used, changing only the percentile of additives.

2.3 Cutting fluid emulsions

Cutting fluid emulsions (oil-in-water – o/w) were prepared using 5, 10, 15, 20, 25, and 30 wt.% cutting fluid in distilled water. The 200mL emulsions were prepared in 250-mL Erlenmeyer flasks with screw caps by adding, quickly and in one step, the required amount of concentrate in water, at room temperature (25°C). The samples were homogenized by mechanical stirring at 700 rpm during 10 minutes.

2.4 Emulsion breakdown (ASTM D 1401)

To promote the destabilization of cutting fluid emulsions, 10mL of aqueous solution of electrolyte, either NaCl at 5 and 10 wt.% or CaCl₂ at 2 and 5 wt.%, were added to 190mL emulsion with constant stirring at 800 rpm, for 5 min, at 25, 40, 50, and 60°C. It was used a Kaehler water

separability tester (Model K39395), in accordance with **ASTM D1401 (2002)**. After stirring, the emulsions were allowed to settle during 30 min. The breakdown of the emulsions was evaluated considering the concentration of electrolytes (NaCl or CaCl_2), temperature, time, and oil phase separation.

2.5 Accelerated stability tests

Accelerated stability was assessed by means of an analytical centrifuge for tracking de-mixing phenomena in dispersions combined with particle size measurement (LUMiSizer - LUM GmbH). The centrifuge employed the STEP technology, which allows the measurement of the intensity of the transmitted infrared radiation (NIR) as a function of time and position over the entire sample length. This equipment analyses up to 12 different samples simultaneously at constant variable centrifugal force. Details are described in **Sobisch and Lerche (2008)** and **Detloff et al. (2007)**. In the experimental procedure it was used 0.5mL emulsion, with 5, 10, 15, 20, 25, and 30 wt.% oil concentration, for 4h at 4000 rpm under temperature of 25°C. From the transmission profiles, it was possible to evaluate the stability of emulsions. According **Sobisch and Lerche (2008)**, the shape and progression of the transmission profiles contains the information on the kinetics of the separation process and allows particle characterization as well as evaluation of particle-particle interactions.

2.6 Characterization of the aqueous and oil phases after emulsion breakdown

The aqueous phase after emulsion breakdown was analyzed considering: turbidity, oil and grease content, pH, and presence of cations and anions. Turbidity was measured using a turbidimeter (Digimed-Tecnal Inc., Model 2100P). An Infracal TOG/TPH Analyzer (HART-T model, WILKS Enterprise Inc.) was used to determine the oil-in-water concentrations. The pH was obtained by using a pHmeter (Digimed Ind. Ltd., Model DM20). Anions were assessed by ion chromatography analysis (Dionex ICS-2000) and cations by ICP-OES (Thermo Inc., model ICAP-6300). The recovered oil phase was analyzed considering the density, total acid number, viscosity, flash point, and corrosiveness, according **Muniz et al. (2008)**.

2.7 Mineral oil recovery

To evaluate mineral oil reuse, 100mL of cutting fluid emulsion was added to a 500-mL separation funnel. After, it was added 10mL of 2wt.% CaCl_2 solution to promote the emulsion destabilization. The mixture was allowed to settle during 10 minutes. The bottom aqueous phase was drained and distilled water was added to wash the oil phase. The mixture was again allowed to settle during 10 minutes. Turbidity of the removed aqueous phase was measured using a Hach Turbidimeter (Model 2100P-Jundilab). This procedure was repeated until the aqueous phase became clear. The oil phase was dried with anhydrous sodium sulfate during 24h, and afterwards, filtered using a cotton plug. It was determined the density, total acid number, kinematic viscosity (40°C), flash point, and corrosiveness to copper of the recovered oil phase.

2.8 Obtaining of emulsions using the recovered mineral oil

Additives were added to the recovered mineral oil to obtain new cutting fluids according to the methodology described in 2.3. Emulsions were prepared using 5, 10, 15, 20, 25, and 30 wt.% cutting fluid in water. Emulsions properties of stability, percentage of foam, corrosiveness, microbiological resistance, conductivity, and particle size were evaluated according to the methodology described in **Muniz et al. (2008)**.

3. RESULTS AND DISCUSSION

3.1 Study of NaCl solution efficiency in emulsions breakdown

NaCl solutions (5 and 10 wt.%) were evaluated in o/w emulsion breakdown (5 to 30 wt.% cutting fluid in water) considering also the influence of temperature (25, 40, 50, and 60°C). The obtained results are shown in Table 1.

For CF1 and CF2 emulsions, with 5 wt.% NaCl solution, it was necessary to heat emulsions until 40°C to obtain 100% emulsion break ($t_{\text{max}} = 9$ min), while with 10 wt.% NaCl solution, 100% emulsion break was observed at 25°C ($t_{\text{max}} = 18$ min).

Table 1. NaCl solution efficiency in the break of cutting fluid emulsions at 25, 40, 50, and 60°C.

Cutting fluid in emulsion (wt.%)	NaCl 5 wt.%				NaCl 10 wt.%			
	25°C	40°C	50°C	60°C	25°C	40°C	50°C	60°C
B/t* - CF1								
5	0/30	100/8	100/7	100/5	100/18	100/3	100/2	100/2
10	0/30	100/5	100/5	100/4	100/15	100/2	100/2	100/2
15	0/30	100/4	100/4	100/3	100/8	100/2	100/2	100/2
20	0/30	100/3	100/4	100/3	100/6	100/2	100/2	100/2
25	0/30	100/3	100/4	100/3	100/4	100/2	100/2	100/2
30	0/30	100/2	100/4	100/3	100/3	100/2	100/2	100/2
B/t - CF2								
5	0/30	100/9	100/9	100/5	100/18	100/2	100/2	100/2
10	0/30	100/5	100/7	100/4	100/15	100/2	100/2	100/2
15	0/30	100/3	100/7	100/3	100/8	100/2	100/2	100/2
20	0/30	100/3	100/5	100/3	100/6	100/2	100/2	100/2
25	0/30	100/3	100/5	100/3	100/4	100/2	100/2	100/2
30	0/30	100/3	100/5	100/3	100/3	100/2	100/2	100/2
B/t - OP 38								
5	0/30	90/30	100/30	100/30	80/30	100/24	100/15	100/15
10	0/30	90/30	100/30	100/30	80/30	100/25	100/20	100/16
15	0/30	80/30	95/30	100/30	80/30	100/30	95/30	95/30
20	0/30	80/30	90/30	97/30	78/30	100/30	90/30	95/30
25	0/30	80/30	90/30	95/30	72/30	95/30	90/30	90/30
30	0/30	80/30	90/30	90/30	50/30	90/30	90/30	90/30
B/t - DROMUS								
5	0/30	0/30	0/30	0/30	0/30	100/30	100/25	100/15
10	0/30	0/30	0/30	0/30	0/30	95/30	100/30	100/18
15	0/30	0/30	0/30	0/30	0/30	95/30	89/30	90/30
20	0/30	0/30	0/30	0/30	0/30	95/30	85/30	85/30
25	0/30	0/30	0/30	0/30	0/30	90/30	85/30	85/30
30	0/30	0/30	0/30	0/30	0/30	87/30	85/30	85/30

*B/t – Emulsion break percentile (%)/ Emulsion break time (min)

For OP38 emulsions, no phase separation occurred with 5 wt.% NaCl solution at 25°C, and between 80 to 100% break was obtained at 40°C, depending on the concentration of cutting fluid in emulsion. As a trend, the less concentrated emulsions had a higher break percentage as a function of NaCl solution concentration and temperature.

For Dromus emulsions, when was used 5 wt.% NaCl solution, all emulsions were stable and no phase separation was observed, considering the experimental maximum time allowed for phase separation (30 min). When it was used 10% NaCl solution, emulsion destabilization was observed at 40°C, in 30 min. However, 100% emulsion break was observed only in low concentrated emulsions.

3.2 Study of CaCl₂ solution efficiency in emulsions breakdown

Table 2 shows the results for the use of CaCl₂ solutions (2 wt.% and 5 wt.%) in emulsion destabilization for all studied systems. For CF1 and CF2, 100% emulsion break was observed with a maximum of 2 min contact time. OP38 and Dromus emulsions also showed 100% emulsion break between 1 and 7 minutes.

CaCl₂ solutions were more efficient in emulsion destabilization, for instance, its ions nullified the repulsive charges between small oil droplets, promoting the formation of larger ones (coalescence) and, after, the migration of the oil phase to the top of the test tubes (creaming). The

Table 2. Time to obtain 100% emulsion break when using CaCl_2 solutions, at 25, 40, 50, and 60°C.

Cutting fluid in emulsion (wt.%)	CaCl ₂ 2 wt.%				CaCl ₂ 5 wt.%			
	25°C	40°C	50°C	60°C	25°C	40°C	50°C	60°C
	t (min)				t (min)			
	CF1 and CF2							
5	2	1	1	1	1	1	1	1
10	2	1	1	1	1	1	1	1
15	2	1	1	1	1	1	1	1
20	2	1	1	1	1	1	1	1
25	2	1	1	1	1	1	1	1
30	2	1	1	1	1	1	1	1
	OP 38							
5	2	2	2	2	2	1	1	1
10	4	2	2	2	3	2	2	2
15	4	3	2	2	4	3	3	3
20	4	4	4	2	4	3	3	3
25	4	4	4	4	5	5	4	3
30	7	4	4	4	5	5	4	4
	DROMUS							
5	2	2	2	2	1	1	1	1
10	2	2	2	2	2	1	1	1
15	3	2	2	2	2	2	1	1
20	3	3	3	2	3	2	2	2
25	3	3	3	2	5	3	2	2
30	4	4	4	4	5	3	2	2

phenomenon described is irreversible and the droplets lose its identity.

3.3 Accelerated stability study

The results of accelerated stability tests are shown in Figures 1 to 4. The plots of light transmittance versus time (transmission profiles), characterizing emulsion stability to centrifugation, were obtained for all studied cutting fluid emulsions (5 to 30 wt.%).

Transmission profiles for CF1 and CF2 emulsions are shown in Figures 1 and 2. The insertion at about 107mm indicates the filling height of the sample (meniscus). The position of the cell bottom is at 130mm. It is important to observe that low transmission means high particle concentration and high transmission means low particle concentration. It was observed the same behavior for all CF1 and CF2 emulsions, with low transmission along the sample length in the beginning and increasing with centrifugation time. It was also observed that the profiles are nearly

evenly spaced, showing that the creaming front moves with low velocity, indicating great stability. The good interaction of oil phase with emulsifier favors stability of these emulsions, providing particles with small size and well distributed along the sample length, making it difficult to obtain oil coalescence and, therefore, providing greater stability to the system. By increasing the oil percentage in the systems (20 to 30 wt.%), a reduction in emulsifier efficiency was observed, obtaining systems with greater particle size, favoring coalescence of droplets, creaming and phase separation.

Transmission profiles for OP38 and Dromus emulsions are shown in Figures 3 and 4. Emulsions with 5 and 10 wt.% cutting fluid were more resistant to creaming during centrifugation. With an increase in oil concentration, the emulsion stability decreased. This is attributed to increasing particle size, with great droplet-droplet interaction, resulting in a reduced time for flocculation and creaming.

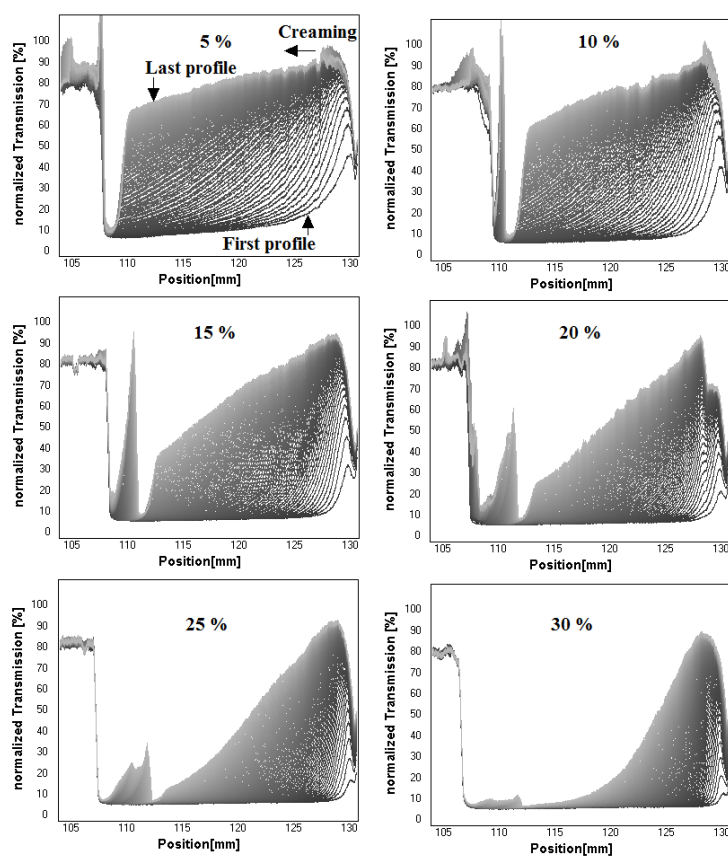


Figure 1. Transmission profiles for CF1 emulsions, 5 to 30 wt.%, during 4h at 4000 rpm (25°C).

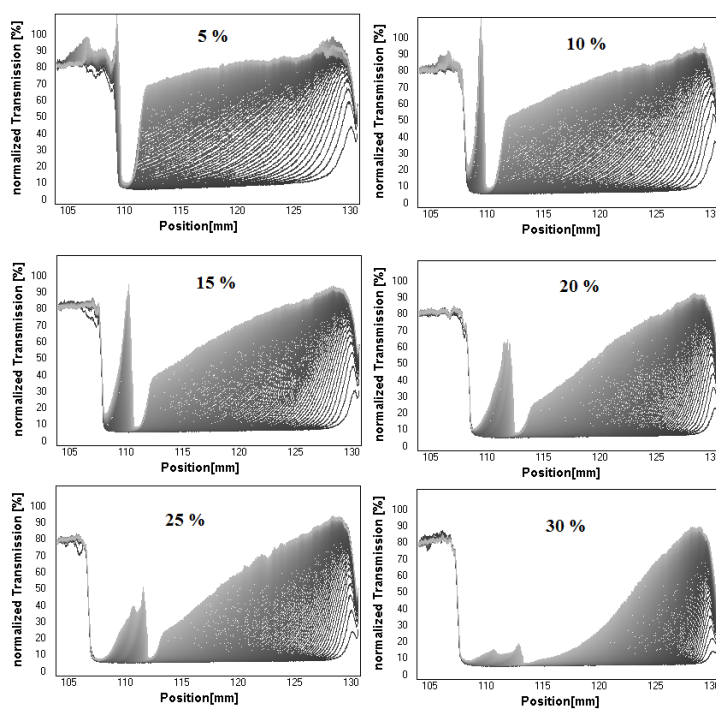


Figure 2. Transmission profiles for CF2 emulsions, 5 to 30 wt.%, during 4h at 4000 rpm (25°C).

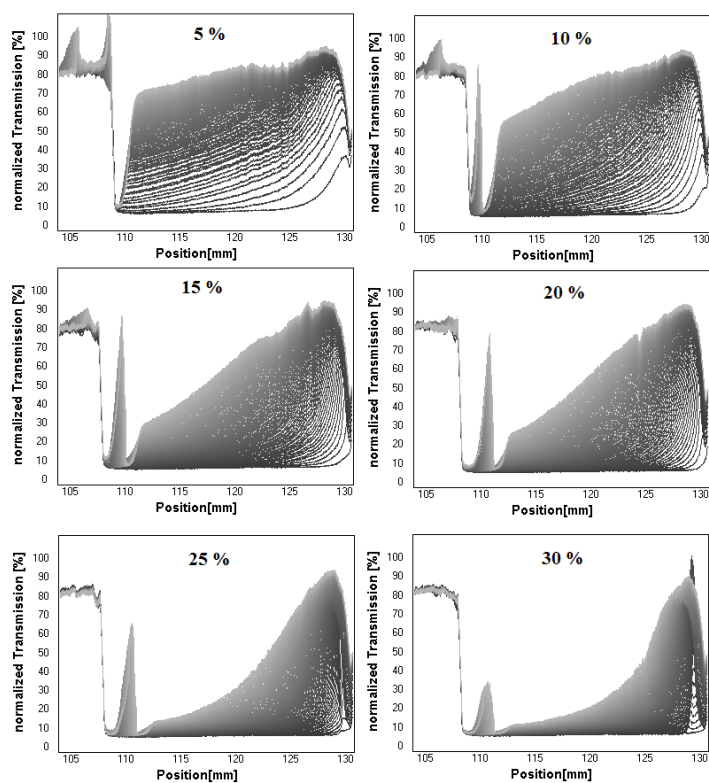


Figure 3. Transmission profiles for OP38 emulsions, 5 to 30 wt.%, during 4h at 4000 rpm (25°C).

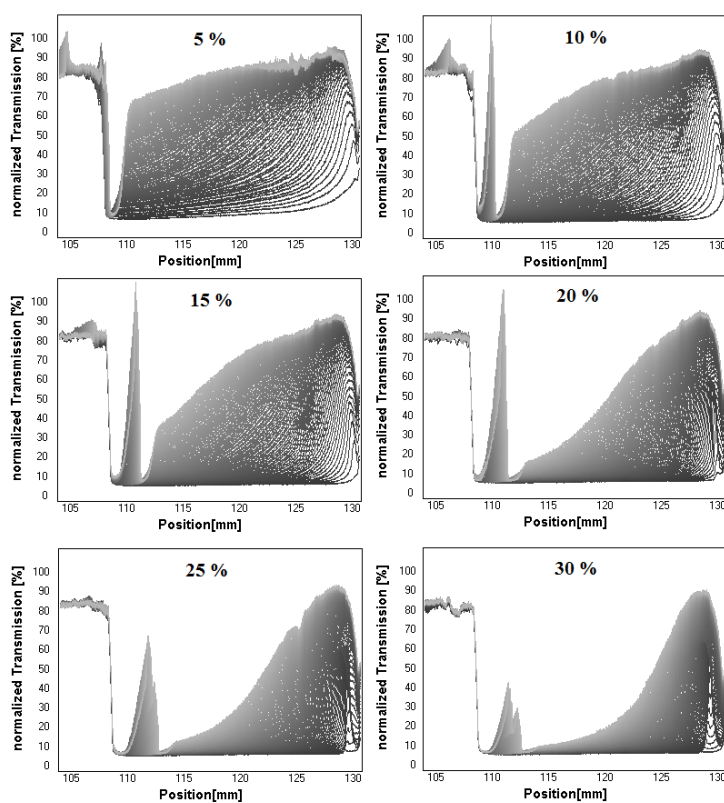


Figure 4. Transmission profiles for Dromus emulsions, 5 to 30 wt.%, during 4h at 4000 rpm (25°C).

Table 3. Physicochemical properties of NH-20 and recovered oil phase for all studied cutting fluids (25°C; 2% CaCl₂ solution).

Parameter	NH-20	CF1	CF2	OP38	Dromus
Density, g/cm ³	0.9023	0.9019	0.9021	0.9025	0.9032
Total acid number, mg KOH/g	0.01	0.2782	0.2798	1.4010	1.3898
Kinematic viscosity (40°C), cSt	21.14	42.25	42.12	43.46	41.33
Flash point, °C	164	158	159	162	160
Corrosiveness to copper (100°C/3h)	1A	1A	1A	1B	1B

3.4 Physicochemical analyses of the recovered oil phases and new cutting fluids

Table 3 shows the physicochemical properties of the mineral oil (NH20) used in CF1 and CF2 formulations and the recovered oil phases after emulsion destabilization using CaCl₂ solution (2 wt.%), at 25°C.

The values of density and flash point for all recovered oils were similar to the ones for NH-20. For NH-20, the values of viscosity and total acid number were lower than those of recovered oils, mainly attributed to residues of additives left in the mineral oil after phase separation. A high total acid number (TAN) indicates higher corrosion tendencies. In agreement with TAN, the values of corrosiveness to copper for Dromus and OP38 fluids were higher than those for CF1 and CF2 formulations.

Additives were incorporated to the recovered oil phases as follows: emulsifying agent (12 wt.%), anticorrosion agent (2 wt.%), biocide (1 wt.%), and antifoaming agent (1 wt.%). Table 4 shows the physicochemical properties of the new cutting fluids.

Comparing the results shown in Table 4 for initial and recovered cutting fluids, it can be observed that the properties are similar, except viscosities values that increased significantly, probably due to residues of additives that remained in the oil phase after emulsion break.

3.5 Properties of cutting fluids emulsions prepared with the recovered oil phase

In order to verify if the cutting fluids with the recovered oil phases provide emulsions that can be applied in industrial processes, oil-in-water emulsions were prepared. It was evaluated emulsion's stability, microbiological resistance, percentage of foam, corrosiveness, conductivity, and particle size.

3.5.1 Stability

The stability of the emulsions was visually assessed during 24h, at 25°C, as to phase separation (creaming), in graduated 100-mL test tubes (with 1-mL subdivisions) in the oil concentrations of 5 wt.%, 15 wt.%, and 30 wt.%. It was observed that the emulsions prepared with all percentages of cutting fluid in water were stable in the studied interval.

Table 4. Physicochemical properties of the cutting fluids: (i) initial formulation and (r) obtained using the recovered oil phase.

Cutting fluid	Density (g/cm ³)	TAN (mg KOH/g)	Viscosity (40°C, cSt)	Flash point (°C)	Corrosiveness (100°C/3h)
CF1 i	0.913	1.33	31.50	151	1A
CF1 r	0.926	1.40	78.75	156	1A
CF2 i	0.915	1.32	34.30	155	1A
CF2 r	0.925	1.42	78.64	158	1A
OP 38 i	0.920	4.47	42.50	160	2A
OP 38 r	0.928	2.24	88.64	163	1A
Dromus i	0.914	2.52	39.80	158	2A
Dromus r	0.926	1.17	84.62	154	1A

Table 5. Microbiological resistance of emulsions prepared with 3 wt.% recovered cutting fluid in water.

Cutting fluid	pH					
	24h	48h	72h	96h	120h	144h
CF1	10.02	8.98	7.85	7.23	6.55	5.78
CF2	9.85	8.99	7.98	7.03	6.46	5.88
OP38	9.83	8.96	8.95	7.46	6.15	5.48
Dromus	9.45	8.75	7.40	6.88	6.02	4.20

Table 6. Corrosion level for emulsions made with 5 wt.% recovered cutting fluid in water.

Cutting fluid	Corrosion level
CF1	2
CF2	2
OP38	2
Dromus	2

Table 7. Emulsions conductivity, at 25°C.

Cutting fluid	Conductivity (μS)					
	5 wt.%	10 wt.%	15 wt.%	20 wt.%	25 wt.%	30 wt.%
CF1	328.0	628.0	765.0	994.0	1156.0	1383.0
CF2	324.0	598.0	887.0	1130.0	1225.0	1399.0
OP38	518.0	544.0	1272.0	1470.0	1640.0	1816.0
Dromus	544.0	983.0	1413.0	1690.0	1718.0	19200

3.5.2 Microbiological resistance

The microbiological resistance of emulsions prepared with 3 wt.% recovered cutting fluid in water was accessed by measuring changes in pH with time. As can be observed in Table 5, all cutting fluid emulsions showed pH > 6 (120h), showing the efficiency of the used biocide.

3.5.3 Percentage of foam

In order to quantify the percentage of foam formation in the emulsions, 58.5mL of distilled water and 1.5mL of cutting fluid were added to stoppered test tubes and submitted to continuous stirring and 30 inversions at 180°, for 20 min (25°C). It was observed the lack of foam formation for all recovered cutting fluids emulsions.

3.5.4 Emulsion corrosion level (ASTM D130, 2010)

When considering the level of corrosion (Table 6), only slight levels were detected, showing the performance of the aminated anticorrosion agent used in the formulations.

3.5.5 Conductivity

Table 7 summarizes the values of conductivity. As can be observed, the lowest values were observed in emulsions with 5 wt.% recovered cutting fluid in water, while in all other concentrations the conductivity was increased. This behavior was similar to the one observed for emulsions prepared with the initial cutting fluids, as reported by [Muniz et al. \(2008\)](#). The emulsions were more stable at 5 wt.%, which is the usual concentration applied in mechanical industries. Yet, it is important to point out that all emulsions remained stable during 24h.

3.5.6 Particle size

Table 8 shows the size of particles made using 15 wt.% recovered cutting fluid in water. It was observed that the developed cutting fluids (CF1 and CF2) presented emulsions with smaller oil droplets, suggesting the existence of a more stable system. However, the efficiency of the emulsifying agent used in the formulation of the recovered cutting fluids made all emulsion systems stable during 24h.

Table 8. Particle size for emulsions made using 15 wt.% recovered cutting fluids.

Cutting fluid	Particle size, nm
CF1	37
CF2	38
OP38	60
Dromus	48

Table 9. Values of turbidity, oil and grease content, pH and presence of cations and anions in the aqueous phase after emulsion destabilization (25°C; 2 wt.% CaCl₂ solution).

Parameter	MAV*	CF1	CF2	OP38	Dromus
Turbidity (NTU)	40	0.50	0.49	1.84	1.06
Oil & Grease (mg/L)	20	3	3	18	98
pH	5 - 9	7.66	7.49	5.33	6.12
Total arsenic (mg/L As)	0.50	<MDL**	< MDL	< MDL	< MDL
Total barium (mg/L Ba)	5.00	0.004	0.004	0.005	0.006
Total boron (mg/L B)	5.00	< MDL	< MDL	< MDL	< MDL
Total cadmium (mg/L Ca)	0.20	0.0013	< MDL	0.0390	< MDL
Total lead (mg/L Pb)	0.50	0.0012	0.0140	< MDL	0.0006
Dissolved copper (mg/L Cu)	1.00	0.003	0.001	0.002	0.002
Hexavalent chromium (mg/L Cr ⁺⁶)	0.10	< MDL	< MDL	< MDL	< MDL
Total tin (mg/L Sn)	4.00	< MDL	0.0046	0.0071	0.0004
Dissolved iron (mg/L Fe)	15.0	0.017	0.014	0.031	0.0097
Total fluoride (mg/L F)	10.0	0.02	0.02	< MDL	0.01
Total mercury (mg/L Hg)	0.01	< MDL	< MDL	< MDL	< MDL
Total nickel (mg/L Ni)	2.00	< MDL	< MDL	< MDL	0.0005
Total ammonia nitrogen (mg/L N)	20.0	3.000	2.130	< MDL	< MDL
Total silver (mg/L Ag)	0.10	< MDL	< MDL	< MDL	< MDL
Total selenium (mg/L Se)	0.30	< MDL	< MDL	< MDL	< MDL
Total Zinc (mg/L Zn)	5.00	0.025	0.020	0.021	0.027

3.6 Characterization of aqueous phase

The aqueous phases obtained after destabilization of cutting fluids emulsions using CaCl₂ solution (2 wt.%), at 25°C, were evaluated. The results were compared with the allowable limits for discharge in surface waters established by Brazilian environmental legislation (CONAMA, 2011). Table 9 shows the results for turbidity, oil and grease content, pH and for all cations and anions evaluated.

As shown in Table 9, all parameters for CF1, CF2, and OP38 are in accordance with the CONAMA (2011), indicating the efficiency of the applied treatment. The oil and grease content for Dromus was very high, despite obtaining 100% emulsion break. For this reason, it is necessary to use an additional polishing treatment to achieve the limit established by Brazilian legislation.

4. CONCLUSIONS

Based on the experimental results, the following conclusions can be drawn:

- The use of calcium chloride was more effective than sodium chloride, indicating that the addition of highly charged ions, such as the ones of the calcium, can effectively induce the destabilization of cutting fluid emulsions;
- By increasing the oil concentration, the emulsion stability decreases, indicating the influence of droplet size in emulsion break;
- The oil phase after emulsion destabilization showed values of viscosity and TAN higher than NH20, indicating the presence of additives in the recovered oil;

- The aqueous phase obtained after emulsion break for CF1, CF2, and OP32 presented all parameters in accordance with allowable limits for discharge in surface waters established by Brazilian environmental legislation;
- It was possible to recover the oil phases of all studied cutting fluid emulsions and to use these oil phases to obtain new cutting fluids with enhanced properties;
- At least, the recovery process of the oil phase is an environmental friendly and economically solution to the problems related with the disposal of used cutting fluid emulsions.

NOMENCLATURE

B– Emulsion breaking percentile (%)

ASTM– American Society for Testing and Materials

CONAMA- National Environmental Council of Brazil

ICP-OES- Inductively coupled plasma optical emission spectrometry

MAV- Maximum allowed value

MDL- Method detection limit

NIR- Transmitted infrared radiation

o/w- Oil-in-water

STEP- Space- and Time-resolved Extinction Profiles

t– Emulsion breaking time (min)

TAN- Total acid number

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